TEXAS AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 196 AUGUST, 1916

DIVISION OF CHEMISTRY

Digestibility of Sugars, Starches, and Pentosans of Roughages

POSTOFFICE:
COLLEGE STATION, BRAZOS COUNTY, TEXAS

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BY

G. S. FRAPS, Ph. D.,
CHEMIST IN CHARGE; STATE CHEMIST

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*As of September 1, 1916.
**In cooperation with the United States Department of Agriculture.

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Digestibility of Sugars, Starches and Pentosans of Roughages

BY

G. S. FRAPS, PH. D., CHEMIST IN CHARGE; STATE CHEMIST.

Comparatively little work has been done upon the composition and digestibility of the nitrogen-free extract of feeding-stuffs. The writer (Bulletin No. 172, N. C. Experiment Station, 1900) has studied the digestibility of sugars and pentosans, and given a review of the literature up to 1900. Further data is given by the writer in Bulletin No. 104 of the Texas Experiment Station. Dr. Frear (Pennsylvania Report, 1903-4) has studied the composition of timothy hay in detail, and Dr. Headden (Bulletin No. 124, Colorado Experiment Station, 1907) has made quite extensive studies into the composition, constituents, and digestibility of a number of feeding-stuffs. As this bulletin is largely a report of progress, we will not go further into the literature of the subject, but will postpone such discussion to a later bulletin.

METHODS OF WORK.

The material used in this work was secured in the digestion experiments described in Bulletin No. 147 (1912) of this Station. For details of the digestion work, reference should be made to that bulletin.

Reducing Sugars.—Five grams substance is added to 75 c.c. water and let stand for thirty minutes, stirring about every five minutes, filtered, and washed to a volume of about 175 c.c. in a 200 c.c. flask. Five c.c. lead subacetate is added and shaken well. Ten c.c. of 10 per cent. sodium sulphate is added and the mixture shaken. Ten c.c. of 10 per cent. copper sulphate is added and shaken and the liquid made up to 200 c.c. It is then filtered immediately through a fluted filter into a dry flask. Thirty c.c. of Allihn's copper solution, 30 c.c. of alkaline tartrate solution, and 35 c.c. water are placed in a beaker and heated to boiling. Then add 50 c.c. of the above solution, heat to boiling, and as soon as it boils, turn over the two minute sand glass, heat two minutes, then filter immediately through a thick asbestos filter without diluting, and wash thoroughly with hot water. Determine copper by Low's method (A. O. A. C. Methods). Calculate to reducing sugars.

Total Sugars.—(b) Fifty c.c. is placed in a beaker, 5 c.c. of concentrated hydrochloric acid added, the beaker placed in a water bath which is at 70°, with a thermometer arranged so that it hangs in the center of the beaker. It should take about two and one-half minutes to reach 69°, and should be maintained at this temperature for seven and one-half minutes. Then cool and neutralize with sodium car-

bonate. Heat up the mixed reagent as in (a), pour into the beaker, heat to boiling and boil two minutes, and complete as in (a). Calculate to dextrose, subtract the reducing sugars, and the result multiplied by 0.95 is the di-sugars or polysaccharoses.

Starch.—Weigh out 4 grams of the material if it is a hay or excrement; if it is corn chops, kafir, rice polish, or a similar concentrate, use 2 grams—and extract with five successive portions of 10 c.c. each of ether on a hardened filter No. 589. Wash the residue from the paper into a beaker with 100 c.c. of water. Run a blank on the malt with each set. Heat on a sand bath to boiling with constant stirring and continue the boiling and stirring thirty minutes. Replace the water lost by evaporation. Immerse the beaker in a water bath and keep it between 55° and 60°. When cooled to 55° C., add 10 c.c. of fresh extract of malt. (See below.) Do not add the malt extract until the liquid is cooled. Digest the mixture with occasional stirring for one hour at 55° to 60° C. Boil a second time for fifteen minutes, replace the water lost by evaporation, cool to 55° and digest as before with 10 c.c. of malt extract for one hour. Heat to boiling, cool, and make up to 250 c.c. in a graduated flask. Filter through a dry paper and remove 200 c.c. of the filtrate to 500 c.c. flask. Plug the flask with cotton wool. Twenty c.c. of the 25 per cent. hydrochloric acid, specific gravity, 1.125, is added and heated for three hours in a boiling water bath, then cooled. Neutralize with carbonate of soda, make up to 500 c.c. and filter through a dry paper. Determine the reducing sugars in the filtrate by the Allihn method. Calculate the total cuprous oxide reduced to dextrose, then subtract the blank in the malt, previously calculated to dextrose. Next divide by the quantity of substance used. The total sugars must be subtracted before calculating to starch.

Malt Extract.—Digest cold two to three hours 20 grams of fresh malt over night with 200 c.c. of water and filter. This solution will not keep over thirty hours. Each time a fresh solution is made up, determine the reducing sugars produced from it, using 20 c.c. and going through the above process with pure water the same as if it contained starch.

Pentosans in Nitrogen-Free Extract.—The digestibility of the pentosans is discussed in another Bulletin (see Bulletin No. 175). The pentosans in the nitrogen-free extract are inserted in the table for the purpose of comparison and discussion.

Reducing Sugars from Hemi-Cellulose.—This term is applied to the sugars produced from material dissolved by approximately N/50 acid and approximately N/50 alkali. Two grams substance was boiled thirty minutes with 200 c.c. water and 20 c.c. N/5 hydrochloric acid, then 40 c.c. N/5 sodium hydroxide added, and the boiling continued for fifteen minutes. It was then filtered through asbestos, the volume of the filtrate made 400 c.c., placed in a 500 c.c. flask, and 40 c.c. of 25 per cent. hydrochloric acid added. The liquid was heated three hours in a boiling water bath, cooled, nearly neutralized with caustic

soda, and made up to 500 c.c. Dextrose was then determined by the Allihn method. As the filtrate contains both the starch and reducing sugars, these were subtracted (as dextrose) from the result, and the remainder taken to be dextrose as reducing sugars from hemi-celluloses. Pentosans were dissolved by the acid and alkali, and partly destroyed (see Bulletin No. 175). Pentosans have nearly the same reducing power as dextrose.

Material Rendered Insoluble by Acid.—The treatment with hydrochloric acid (25 per cent.) in the above method rendered some of the material insoluble, as a brown or black powder. This was filtered off on asbestos, washed with water, and the quantity estimated. This substance is, of course, indefinite.

Soluble Residue.—The "residue" is left after subtracting the sugars, starch, pentosans and material rendered insoluble by acid, from the soluble nitrogen-free extract. It represents the nitrogen-free extract soluble in approximately N/50 acid and alkali, not included in the groups named.

Soluble Nitrogen-Free Extract.—We use this term to designate the nitrogen-free extract dissolved by approximately N/50 acid and alkali as described in the following method:

Reagents, Fifth Normal Sulphuric Acid.—Dilute 25 c.c. sulphuric acid with 4000 c.c. water and titrate 10 c.c with N/10 ammonia and cochineal. Adjust so tht 10 c.c. requires from 19.9 to 20.2 c.c. ammonia to neutralize.

Caustic Soda.—Dissolve 35 grams caustic soda pure by alcohol in 4000 c.c. water. Titrate 10 c.c. with N/5 hydrochloric acid and cochineal and adjust so that 10 c.c. requires between 9.95 to 10.05 c.c. of the acid.

Estimation.—Extract 2 grams material with ether. Transfer to tall beaker and add 200 c.c. boiling water (measured with a cylinder) and 20 c.c. fifth normal sulphuric acid, measured with a pipette. Boil thirty minutes, using a round-bottom flask as a condenser. While boiling, add 40 c.c. fifth normal caustic soda measured with a pipette and continue to boil for fifteen minutes. Filter on asbestos, wash with hot water, then once with alcohol and dry ten hours. Weigh, ignite, and weigh again. The loss in weight is the total material insoluble in approximately N/50 acid and alkali. This includes crude fiber and proteins. The proteins were determined, and proteins plus crude fiber subtracted from the insoluble residue. The difference is the insoluble nitrogen-free extract. This is not strictly correct, as the crude fiber contains some protein. The total nitrogen-free extract less the insoluble gives the soluble nitrogen-free extract.

COMPOSITION OF THE FEEDS.

Table 1 shows the percentage composition of the roughages used in the experiments. Table 2 shows the percentage composition of the nitrogen-free extract.

TABLE 1.—COMPOSITION OF ROUGHAGES—PER CENT.

Lab. No.	Name of Feed.	Sugars		Starch.	Soluble Pentosans.	Reducing sugar from hemicellulose.	Rendered insoluble by acid.	Total except sugars from hemicellulose.	Soluble residue.	Total N. F. Extract soluble.	Insoluble N. F. Extract	Total N. F. Extract.
		Mono.	Di.									
3277	Alfalfa hay used in Experiment No. 3.	1.84	0.95	1.46	5.90	3.55	4.75	14.90	12.07	26.97	7.41	34.78
4252	Bermuda hay used in Experiment No. 12.	2.20	1.41	1.08	4.34	0.71	2.63	11.66	5.89	17.55	28.71	46.26
3609	Burr clover used in Experiment No. 6.	1.17	.11	1.90	6.18	3.15	6.44	13.80	8.70	24.50	7.41	31.91
3833	Buffalo grass used in Experiment No. 9.	2.66	.84	4.07	4.93	0.39	2.27	14.77	4.39	19.16	25.71	44.87
4557	Corn shucks used in Experiment No. 17.	1.37	.17	2.01	12.11	8.40	1.85	17.51	7.66	25.17	29.34	54.51
3220	Cowpea hay used in Experiment No. 1.	1.33	1.22									34.42
4552	Guam grass used in Experiment No. 16.	2.52	.57	1.14	4.74	0.43	5.81	14.78	7.96	22.74	26.89	49.63
3587	Johnson grass hay used in Experiment No. 4.	1.57	.07	1.06	5.71	4.06	3.79	12.20	6.84	19.04	22.83	41.87
4238	Johnson grass hay used in Experiment No. 10.	2.72	.59	1.89	4.82	0.86	3.54	13.56	7.67	21.23	23.50	44.73
4546	Kafir fodder used in Experiment No. 15.	4.70	.59	1.33	5.05	0.52	2.37	14.04	10.05	24.09	20.35	44.44
4247	Millet used in Experiment No. 11.	2.35	.98	11.49	9.05	8.61	3.28	27.15	2.47	29.62	18.27	47.89
3595	Oat hay used in Experiment No. 5.	2.24	.30	5.01	4.08	1.39	3.73	15.36	4.68	20.04	24.35	44.39
4259	Peanut hay used in Experiment No. 13.	2.27	2.18	3.45	5.04	0.36	3.97	16.91	16.33	33.24	6.65	39.89
4277	Para grass used in Experiment No. 14.	4.35	0.88	0	5.28	2.70				23.07	23.10	46.17
3625	Rice straw, Japan, used in Experiment No. 7.	1.55	0.15	5.90	2.45	3.09	2.21	12.26	3.09	15.35	22.17	37.52
4663	Rice straw, Honduras, used in Experiment No.18	0.68	0.12	1.72	3.78	3.79	2.58	8.88	7.90	16.78	23.72	40.50
3224	Sorghum hay used in Experiment No. 2.	4.86	0.65	1.29	4.16	0.40	3.63	14.59	8.15	22.74	24.05	46.49
3649	Vetch hay used in Experiment No. 8.	0.70	0.32	0.88	5.23	4.48	5.94	13.07	14.02	27.09	10.21	37.30

TABLE 2.—PERCENTAGE COMPOSITION OF NITROGEN-FREE EXTRACT.

Lab. No.	Name of Feed.	Sugars		Starch.	Soluble Pentosans.	Reducing sugar from hemicellulose	Rendered insoluble by acids.	Total except sugars from hemicellulose	Soluble residue.	Total N. F. Extract soluble.	Insoluble N. F. Extract.
		Mono.	Di.								
3277	Alfalfa hay used in Experiment No. 3.	5.3	2.7	4.2	17.0	10.2	13.7	42.8	34.7	77.5	21.3
4252	Bermuda hay used in Experiment No. 12.	4.8	3.0	2.3	9.4	1.5	5.7	25.2	12.7	37.9	62.1
3609	Burr clover used in Experiment No. 6.	3.7	0.3	6.0	19.4	9.9	20.2	43.4	37.3	76.8	23.2
3883	Buffalo grass used in Experiment No. 9.	5.9	1.9	9.1	11.0	0.9	5.1	32.9	9.8	42.7	57.3
4557	Corn shucks used in Experiment No. 17.	2.5	0.3	3.7	22.2	15.4	3.4	32.1	14.1	46.2	53.8
3220	Cowpea hay used in Experiment No. 1.	3.9	3.5	.....	.....	.....	.....	.....	.....	.....	.....
4552	Guam grass used in Experiment No. 16.	5.1	1.1	2.3	9.6	0.9	11.7	29.9	16.0	45.8	54.2
3587	Johnson grass used in Experiment No. 4.	3.7	0.2	2.5	13.6	9.7	9.1	29.1	16.3	45.5	54.5
4238	Johnson grass used in Experiment No. 10.	6.1	1.3	4.2	10.8	1.9	7.9	30.3	17.2	47.5	52.5
4546	Kafir fodder used in Experiment No. 15.	10.6	1.3	3.0	11.4	1.2	5.3	3.2	22.6	54.2	45.8
4247	Millet used in Experiment No. 11.	4.9	2.0	24.0	18.9	18.0	6.8	56.7	5.2	61.8	38.1
3595	Oat hay used in Experiment No. 5.	5.0	0.7	11.3	9.2	3.1	8.4	34.6	10.5	45.2	54.9
4259	Peanut hay used in Experiment No. 13.	5.7	5.5	8.6	12.6	0.9	10.0	42.4	40.9	83.3	16.7
4277	Para grass used in Experiment No. 14.	9.4	1.9	0	11.4	5.8	.....	.....	.....	50.0	50.0
3625	Rice straw, Japan, used in Experiment No. 7.	4.1	0.4	15.7	6.5	8.2	5.9	32.7	8.2	40.9	59.1
4663	Rice straw, Honduras, used in Experiment No. 18.	1.7	0.3	4.2	9.3	9.4	6.4	21.9	19.5	41.4	58.6
3224	Sorghum hay used in Experiment No. 2.	10.5	1.4	2.8	8.9	0.9	7.8	31.4	17.5	49.9	51.7
3649	Vetch hay used in Experiment No. 8.	1.9	0.9	2.4	14.0	12.0	15.9	35.0	37.6	72.6	27.4

The feeds contain only small percentages of sugars and starch. An exception is millet, which contained some grain. Rice straw apparently contains over 5 per cent. starch, but this is probably due to substances other than starch.

The reducing sugars formed from the material dissolved by the approximately N/50 acid and alkali are not equal to the pentosans so dissolved. As shown in another Bulletin (No. 175), pentosans or pseudo-pentosans, are destroyed by the treatment with these reagents. The quantity destroyed, however, is less than the difference between the soluble pentosans and the reducing power of the solution, so that further destruction of pentosans must take place during the inversion with hydrochloric acid. We should further expect a production of hexose sugars, due to the solvent action of the N/50 acid or alkali upon hemi-celluloses, but these must have also been in part or largely destroyed by the inversion with hydrochloric acid.

During the inversion with hydrochloric acid, a black powder separated out, strongly resembling the so-called "humic acid" formed by the action of acids upon sugar. This substance was filtered off, and estimated. The determination of such an indefinite body can lay little claim to accuracy. We should judge that, in part at least, it is derived from sugars.

The estimation of the pentosans and hexoses dissolved from feeding-stuffs by dilute acids, thus requires study, as both pentosans and hexosans are no doubt destroyed in the process of the estimation, so that the results are too low.

The nitrogen-free extract dissolved by approximately N/50 acid and alkali from legumes and from non-legumes is quite different in proportion. While from one-third to one-half of the nitrogen-free extract of non-legumes is dissolved, from legumes three-fourths to four-fifths dissolves. The nitrogen-free extract of legumes is thus more readily soluble than that of non-legumes.

DIGESTIBILITY OF THE MATERIALS.

Table 3 shows the co-efficients of digestibility of the groups of materials estimated, which are worked out in Table 9.

TABLE 3.—COEFFICIENTS OF DIGESTIBILITY.

Lab. No.	Name of Feed.	Sugars		Starch.	Soluble Pentosans.	Reducing sugar from hemicellulose	Rendered insoluble by acids.	Soluble residue.	Total N. F. Extract soluble.	Insoluble N. F. Extract.	Total N. F. Extract.
		Mono.	Di.								
3277	Alfalfa hay used in Experiment No. 3.	98.5	98.2	93.8	75.7	61.6	8.59	74.7	71.6	77.1	65.0
4252	Bermuda hay used in Experiment No. 12.	98.4	98.7	62.9	55.5	.....	.....	.....	59.8	43.6	50.2
3609	Burr clover used in Experiment No. 6.	98.7	82.9	82.4	85.4	64.0	70.3	92.2	85.1	45.8	75.9
3883	Buffalo grass used in Experiment No. 9.	98.8	98.1	91.0	65.4	0	91.9	28.2	62.9	55.2	58.0
4557	Corn shucks used in Experiment No. 17.	97.8	98.7	92.7	80.9	70.8	0	52.1	63.1	56.5	60.6
3220	Cowpea hay used in Experiment No. 1.	90.1	99.1	.....	.....	.....	.....	.....	.....	.....	65.3
4552	Guam grass used in Experiment No. 16.	98.8	98.5	68.4	60.2	0	4.5	69.2	6.34	51.7	53.8
3587	Johnson grass hay used in Experiment No. 4.	98.6	89.8	38.9	65.7	67.5	11.1	37.6	49.1	52.1	52.3
4238	Johnson grass hay used in Experiment No. 10.	94.5	98.3	95.2	76.0	0	18.8	61.5	64.6	57.7	61.0
4546	Kafir fodder used in Experiment No. 15.	99.4	99.1	93.7	80.1	0	3.3	77.3	78.4	55.0	69.4
4247	Millet used in Experiment No. 11.	95.9	93.6	71.5	84.3	91.9	7.1	.04	67.3	45.1	59.3
3595	Oat hay.....used in Experiment No. 5.	99.4	69.9	99.1	73.2	14.7	6.2	0	56.1	69.3	66.8
4259	Peanut hay used in Experiment No. 13.	97.2	97.9	99.5	88.4	0	92.2	87.9	91.7	3.3	74.3
4277	Para grass used in Experiment No. 14.	93.7	99.6	.....	49.7	17.9	.....	.....	.....	37.5	46.9
3625	Rice straw, Japan, used in Experiment No. 7.	97.5	99.7	95.9	23.6	46.7	0	53.4	46.9	42.6	45.0
4663	Rice straw, Honduras, used in Experiment No. 18.	88.6	56.2	65.5	51.7	71.4	0	67.5	51.8	43.6	47.3
3224	Sorghum hay used in Experiment No. 2.	99.7	95.5	79.1	71.3	0	4.9	.....	67.3	62.9	65.0
3649	Vetch hay used in Experiment No. 8.	95.7	99.2	91.2	71.0	64.2	79.8	54.0	65.8	62.7	74.5

The sugars are highly digested. This is in accord with previous work (N. C. Bulletin No. 172, Texas Bulletin No. 104). One or two cases of lower digestibility occur, but as the excrements contain other reducing substances in addition to sugars, it is quite possible that the lower results are due to these substances and not to the presence of sugars.

Starch also has a high digestibility. There are some cases in which the digestibility is low, notably with millet. It is probable that other substances in addition to starch are dissolved by the treatment with malt, and the low results in these particular cases may be due to these other substances, which may even possibly be formed during the process of digestion.

The reducing sugars formed from the hemi-celluloses exhibit quite marked variations in digestibility from 0 or less, to 92 per cent. This may be ascribed in part at least to the unsatisfactory character of this determination, due to the partial destruction of sugars already discussed. It may also be in part due to the production, during the fermentation in the intestines, of soluble products from materials previously insoluble.

The material rendered insoluble by acids is an indefinite group, and its digestibility varies. It is a question if much significance can be attached to this group. Pentosans were determined in a number of these insolubles, with the following results:

No.	Description.	Per Cent. Insoluble.	Per Cent. Pentosans.
3649	Vetch hay	5.94	0.79
3700	Excrement, vetch hay	3.21	.00
3877	Excrement, rice straw	5.88	.00
4249	Excrement, millet	7.07	.00
4254	Excrement, Bermuda	5.68	.00
4559	Excrement, corn shucks	7.52	.00
3609	Burr clover	6.44	0.94
3623	Excrement, burr clover	6.97	0.38
4238	Johnson grass hay	3.54	0.31
4240	Excrement, Johnson grass	7.59	0.43
4552	Guam grass	5.81	0.30
4554	Excrement, guam grass	11.69	0.29

The substances selected contained a high percentage of material made insoluble. If pentosans are made insoluble by the hydrochloric acid, their character is destroyed, so that they no longer yield furfural.

Nitrogen was also determined in some of the insolubles, and the results calculated to protein. Results are in the table:

No.	Description.	Per Cent. Insoluble.	Per Cent. Pentosans.
3258	Excrement, sorghum hay	8.90	1.56
3589	Excrement, Johnson grass	6.83	1.62
3595	Oat hay	3.73	1.14
3597	Excrement, oat hay	10.44	2.44
3625	Rice straw	2.21	0.50

No.	Description.	Per Cent. Insoluble.	Per Cent. Pentosans.
3883	Buffalo grass hay	2.27	0.60
4247	Millet	3.28	0.69
4252	Bermuda hay	2.63	0.70
3877	Excrement, rice straw	5.88	1.36
4249	Excrement, millet	7.07	4.30
4254	Excrement, Bermuda	5.68	3.38

This material, therefore, is composed for the most part of other substances than pentosans or protein.

The soluble residue is in some cases digested more, in others, less, than the total soluble nitrogen-free extract. This soluble residue includes the indefinite group of substances rendered insoluble by acids, and we cannot assume that they are rendered insoluble in quantitative proportions, but must await results of further experiments as to their nature.

The total soluble nitrogen-free extract (soluble in approximately N/50 acid and alkali) is digested to a greater extent than the insoluble nitrogen-free extract. There are some exceptions to this statement; namely, oat hay and alfalfa.

TABLE 4.—DIGESTIBLE CONSTITUENTS IN PERCENTAGE OF THE FOOD.

Lab. No.	Name of Feed.	Sugars		Starch.	Reducing sugar from hemi-cellulose.	Insoluble by acids.	Residue.	Total N. F. Extract Soluble.	Insoluble N. F. Extract.
		Mono.	Di.						
3277	Alfalfa hay used in Experiment No. 3.	1.81	.93	1.37	2.19	4.08	9.02	19.31	5.71
4252	Bermuda hay used in Experiment No. 12.	2.6	1.39	.68	.....	.....	.....	10.49	12.52
3609	Burr clover used in Experiment No. 6.	1.15	.09	1.57	2.02	4.53	8.02	20.85	3.39
3883	Buffalo Grass used in Experiment No. 9.	2.63	.82	3.70	0	2.09	2.24	12.05	14.19
4557	Corn shucks used in Experiment No. 17.	1.34	.17	1.86	5.95	.....	3.99	15.88	16.58
3220	Cowpea hay used in Experiment No. 1.	1.20	1.21	.....	.....	.....	.....	.....	.....
4552	Guam grass used in Experiment No. 16.	2.49	.56	.78	.....	.26	5.51	14.42	13.90
3587	Johnson grass hay used in Experiment No. 4.	1.55	.06	.41	2.74	.42	2.57	9.34	11.89
4238	Johnson grass hay used in Experiment No. 10	2.68	.58	1.80	0	.67	4.72	13.71	13.56
4546	Kafir fodder used in Experiment No. 15.	4.67	.58	1.25	0	.08	7.77	18.89	11.19
4247	Millet used in Experiment No. 11.	2.25	.92	8.22	7.91	.23	.01	19.93	8.24
3595	Oat hay used in Experiment No. 5.	2.23	.21	4.96	.20	.23	0	11.24	16.87
4259	Peanut hay used in Experiment No. 13.	2.21	2.13	3.43	0	3.66	14.35	30.48	.....
4277	Para grass used in Experiment No. 14.	4.08	.87	.....	.48	.....	.....	.....	8.66
3625	Rice straw, Japan, used in Experiment No. 7.	1.51	.15	5.66	1.44	.....	1.65	7.20	9.44
4633	Rice straw, Honduras, used in Experiment No. 18.	.60	.07	1.13	2.71	0	5.33	8.69	10.34
3224	Sorghum hay used in Experiment No. 2.	4.85	.62	1.02	.....	.....	.....	15.30	15.13
3649	Vetch hay used in Experiment No. 8.	.67	.32	.80	2.88	4.74	7.57	17.82	6.40

SUGARS, ETC., BY 1¼ PER CENT. SULPHURIC ACID AND CAUSTIC SODA.

Only a limited amount of work was done along this line.

Methods.—The residue from the boiling with N/50 acid and alkali was returned to the beaker and boiled with 1¼ per cent. sulphuric acid as in the regular crude fiber method.

The *filtrate* was neutralized with caustic soda, made up to 400 c.c., 40 c.c. of hydrochloric acid 25 per cent added, and heated three hours in a boiling water bath. The *insoluble* was then determined on some of the materials. The solution was made up to 500 c.c. and reducing sugars determined by the Allihn method.

The residue was returned to the beaker and boiled with 1¼ per cent. caustic soda, as in the method for crude fiber. It was then filtered, and the filtrate neutralized with sulphuric acid and boiled with acid as described above. The insoluble was determined as described above. Nitrogen was determined in some of the insoluble products.

TABLE 5.—PERCENTAGE SUGARS, ETC., PRODUCED BY BOILING WITH ACIDS AND ALKALI.

Lab. No.		Sugars by 1 1-4 per cent Sulphuric.	Insoluble preciptate from Acid.	Sugars by 1 1-4 per cent Caustic.	Insoluble Preciptate from Alkali.	Protein insoluble from Alkali.	Insoluble Nitrogen Free Extract.
3224	Sorghum hay	8.55	.....	1.67	.....	.....	24.05
3258	Sorghum excrement	8.55	0.59	2.25	11.12	.....	23.83
3277	Alfalfa hay	2.55	.....	1.55	.....	.....	7.41
3279	Alfalfa excrement	3.15	.....	1.12	.....	.....	13.74
3587	Johnson grass hay	7.45	.....	0.75	.....	.....	22.83
3581	Johnson grass excrement	7.80	0.54	0.85	12.04	2.40	22.79
3595	Oat hay	11.50	0.57	1.23	4.67	0.93	24.35
3597	Oat hay excrement	8.80	0.70	1.23	7.45	1.24	20.39
3609	Burr clover	2.90	0.67	1.70	3.36	.....	7.41
3623	Burr clover excrement	4.03	0.78	0.43	7.76	.....	13.76
3625	Rice straw	11.23	0.78	0.95	4.76	.75	22.17
3877	Rice straw excrement	10.55	0.60	0.33	6.48	1.06	21.82
3649	Vetch hay	3.39	0.40	0.11	2.53	.....	10.21
3780	Vetch hay excrement	5.65	0.57	0.28	4.05	.....	10.86
3883	Buffalo grass hay	12.00	0.41	.....	6.44	1.30	25.71
3885	Buffalo grass excrement	9.10	.....	0.13	1.62	.....	25.87
4238	Johnson grass hay	10.65	0.48	0.45	6.57	.....	23.50
4240	Johnson grass excrement	9.00	0.36	0.56	10.45	.....	23.06
4247	Millet	8.97	0.39	0.48	4.33	0.70	18.27
4249	Millet excrement	10.30	0.70	0.43	8.35	1.36	23.97
4252	Bermuda	15.50	0.59	1.03	6.02	0.75	28.71
4254	Bermuda excrement	13.12	0.48	1.20	8.80	1.54	31.19
4259	Peanut hay	1.80	.....	0.75	.....	.....	6.65
4261	Peanut hay excrement	4.40	.....	0.60	.....	.....	20.18
4546	Kafir fodder	10.10	.....	0.35	.....	.....	20.35
4548	Kafir fodder excrement	10.30	.....	0.45	.....	.....	25.43
4552	Guam grass	12.45	0.67	0.43	8.13	.....	26.89
4554	Guam grass excrement	12.72	0.67	0.66	9.43	.....	26.83
4557	Corn shucks	15.18	0.59	0.85	3.75	0.62	29.31
4559	Corn shucks excrement	11.90	0.25	0.65	7.17	.....	25.72
4663	Rice straw	10.00	.....	0.85	.....	.....	23.72
4666	Rice straw excrement	9.05	.....	0.90	.....	.....	23.36

Table 5 contains the results of this work expressed in percentage of the feed. Considerable quantities of sugars are produced by boiling with 1¼ per cent. sulphuric acid, and little insoluble material is formed during the hydrolysis with hydrochloric acid. The legumes produce much lower quantities of sugars, but contain less insoluble nitrogen-free extract.

Boiling with the 1¼ per cent. caustic soda produces only small quantities of sugars, but considerable quantities of insoluble precipitates are formed in the subsequent hydrolysis with acid. The precipitate contain some proteids, as shown in the table, but, after deducting this, large quantities remain, which make up comparatively large proportions of the feed. The nature of this precipitate and its mother substance requires further study.

TABLE 6.—PERCENTAGE SUGARS OF INSOLUBLE NITROGEN-FREE EXTRACT, ETC., PRODUCED BY BOILING WITH ACID AND ALKALI.

Lab. No.		Sugars by 1 1-4 per cent Sulphuric.	Sugars by 1 1-4 per cent Caustic.	Insoluble preciptate from Alkali.	Protein insoluble from Alkali.	Total sugar extracted.
3224	Sorghum hay	35.55	6.94	.....	.....	42.49
3258	Sorghum hay excrement	35.87	9.44	46.65	.....	45.31
3277	Alfalfa hay	34.42	20.93	.....	.....	55.35
3279	Alfalfa hay excrement	22.93	8.15	.....	.....	31.08
3587	Johnson grass hay	32.63	3.29	.....	.....	35.92
3589	Johnson grass hay excrement	34.23	3.73	52.83	10.53	37.96
3595	Oat hay	47.23	5.40	19.18	3.82	52.63
3597	Oat hay excrement	43.16	6.03	36.53	6.08	49.19
3609	Burr clover	39.15	22.95	45.36	.....	62.10
3623	Burr clover excrement	29.29	3.12	56.39	.....	32.41
3625	Rice straw	50.66	4.29	21.47	3.38	54.95
3877	Rice straw excrement	48.35	1.51	29.70	4.86	49.86
3649	Vetch hay	33.20	1.08	24.68	.....	34.28
3780	Vetch hay excrement	52.03	2.58	37.29	.....	54.61
3883	Buffalo grass hay	46.68	.....	25.05	5.06	.....
3885	Buffalo grass hay excrement	35.17	0.50	6.26	.....	35.67
4238	Johnson grass hay	45.32	1.91	27.96	.....	47.23
4240	Johnson grass hay excrement	39.03	2.43	45.32	.....	41.46
4247	Millet	49.09	2.63	23.70	3.83	51.72
4249	Millet excrement	42.97	1.79	34.83	5.67	44.76
4252	Bermuda	53.99	3.59	20.97	2.61	57.58
4254	Bermuda excrement	42.06	3.85	28.21	4.93	45.91
4259	Peanut hay	27.07	11.28	.....	.....	38.35
4261	Peanut hay excrement	21.80	2.97	.....	.....	24.77
4546	Kafir fodder	49.63	1.71	.....	.....	51.34
4548	Kafir fodder excrement	40.50	1.77	.....	.....	42.27
4552	Guam grass	44.64	1.54	30.24	.....	46.18
4554	Guam grass excrement	47.40	2.46	35.15	.....	49.86
4557	Corn shucks	51.79	2.90	12.78	2.11	54.69
4559	Corn shucks excrement	46.27	2.53	27.87	.....	48.80
4663	Rice straw	42.16	3.58	.....	.....	45.74
4666	Rice straw excrement	38.74	3.85	.....	.....	42.59

Table 6 shows the percentage of sugars, etc., based upon the insoluble nitrogen-free extract as 100. This table brings out clearly the large proportion of sugars produced from the material dissolved by boiling 1.25 per cent. sulphuric acid, the small quantity from the material dissolved by boiling, 1.25 per cent. caustic soda, and the large quantity of insoluble precipitate from the material dissolved by alkali.

It is, of course, open to question whether all the reducing material formed in this process consists of sugars. It is also a question to be decided, whether the method employed secured the maximum quantity of sugars from the dissolved materials.

TABLE 7.—COEFFICIENTS OF DIGESTIBILITY AND QUANTITY DIGESTED OF SUGARS PRODUCED BY ACID AND ALKALI.

Lab. No.		Coefficient of Digestibility.			Quantity digested from 100 lbs. feed.		
		Insoluble Nitrogen Free Extract.	Sugars by 1 1-4 per cent Sulphuric.	Sugars by 1 1-4 per cent Caustic.	Insoluble Nitrogen Free Extract.	Sugars by 1 1-4 per cent Sulphuric.	Sugars by 1 1-4 per cent Alkali.
3224	Sorghum hay	62.9	65.8	58.5	15.15	5.63	.98
3277	Alfalfa hay	77.1	53.7	72.4	5.71	1.37	1.12
3587	Johnson grass hay	52.1	49.7	45.7	11.89	3.70	.48
3595	Oat hay	69.3	72.6	64.2	16.87	8.35	.79
3609	Burr clover	45.8	61.6	93.0	3.39	1.79	1.58
3625	Rice straw	42.6	47.3	80.5	9.44	5.31	.76
3649	Vetch hay	62.7	37.9	6.8	6.40	1.28	.01
3883	Buffalo grass hay	55.2	66.0	.....	14.19	7.92	.....
4238	Johnson grass hay	57.7	66.7	50.9	13.56	7.10	.23
4247	Millet	45.1	52.3	62.8	8.24	4.69	.30
4252	Bermuda	43.6	57.0	40.9	12.52	8.84	.42
4259	Peanut hay	3.3	20.7	74.0	.....	0.37	.56
4546	Kafir fodder	55.0	61.4	51.6	11.19	6.20	.18
4552	Guam grass	51.7	50.6	25.8	13.90	6.30	.11
4557	Corn shucks	56.5	69.4	97.0	16.58	10.53	.82
4663	Rice straw	43.6	50.1	41.6	10.34	5.01	.35

Table 7 contains the coefficients of digestibility of the sugars produced, and also the quantities of digestible sugars formed.

An examination of this table shows considerable digestible material which is not reduced to the sugar form. It is, of course, true that there is probably a loss in transforming the carbohydrates present to sugars. On the other hand, it is probable that a considerable portion of the deficiency is due to the presence of substances other than carbohydrates.

This work is being continued.

TABLE 8.—COMPOSITION OF EXCREMENTS.

Lab. No.		Sugars		Starch	Pentosans in N. F. Extract.	Reducing sugars from hemicellulose.	Rendered insoluble by acid.	Total except sugars from hemicellulose.	Residue.	Total N. F. Extract. soluble.	Insoluble N. F. Extract.	Total N. F. Extract.
		Mono.	Di.									
3222	Excrement sheep 2...	0.29	0.03	0.05	.....	.....	.....	.....	.....	.....	.....	27.65
3223	Excrement sheep 3...	0.32	0.02	0.03	.....	.....	.....	.....	.....	.....	.....	28.28
3256	Excrement sheep 1...	0.05	0.19	0.70	3.71	2.64	8.90	13.55	5.60	19.15	23.83	42.98
3259	Excrement sheep 2...	0.02	0.03	0.67	2.82	2.54	.....	.....	.....	19.77	23.63	43.40
3260	Excrement sheep 3...	0.04	0.01	0.76	2.91	2.62	.....	.....	.....	19.93	23.73	43.66
3279	Excrement sheep 2...	0.02	.01	.29	3.93	3.61	1.76	6.01	8.03	14.04	13.74	27.78
3280	Excrement sheep 3...	.10	.04	.31	3.65	3.55	.....	.....	.....	14.26	14.24	28.50
3281	Excrement sheep 4...	.10	.08	.14	3.84	3.75	.....	.....	.....	14.00	14.08	28.08
3589	Excrement sheep 1...	.04	.01	1.42	2.94	2.66	6.83	11.24	8.65	19.89	22.79	42.68
3590	Excrement sheep 3...	.03	.02	1.45	4.49	3.33	.....	.....	.....	20.50	22.47	42.97
3591	Excrement sheep 4...	.07	.01	1.16	4.87	2.82	.....	.....	.....	20.15	23.04	43.19
3597	Excrement sheep 1...	.03	.02	.18	3.51	3.22	10.44	14.18	15.40	29.58	20.39	49.97
3598	Excrement sheep 4...	.04	.03	.10	2.70	3.49	.....	.....	.....	20.24	21.27	41.51
3623	Excrement sheep 2...	.08	.12	1.72	2.61	3.96	6.97	11.50	2.47	13.97	13.76	27.73
3624	Excrement sheep 3...	.04	.02	.70	3.91	4.24	.....	.....	.....	12.51	15.26	27.77
3877	Excrement sheep 2...	.06	.01	.35	3.28	3.09	5.88	9.58	5.10	14.68	21.82	36.50
3878	Excrement sheep 3...	.06	.01	.56	3.20	3.15	.....	.....	.....	14.18	23.12	37.30
3879	Excrement sheep 4...	.08	.01	.35	3.49	2.56	.....	.....	.....	14.75	22.78	37.53
3700	Excrement sheep 1...	.08	.01	.21	4.06	4.30	3.21	7.57	17.29	24.86	10.86	35.72
3885	Excrement sheep 2...	.08	.01	.77	3.89	3.34	3.75	8.50	7.42	15.92	25.87	41.79
3886	Excrement sheep 3...	.06	.06	.86	4.21	3.62	.....	.....	.....	15.91	25.55	41.46
3887	Excrement sheep 4...	.07	.02	.36	3.12	4.12	.....	.....	.....	15.70	26.14	41.84
4240	Excrement sheep 1...	.09	.01	.18	3.21	3.95	7.59	11.08	7.80	18.88	23.06	41.94
4241	Excrement sheep 2...	.11	.01	.26	2.96	3.88	.....	.....	.....	18.71	26.39	45.10
4242	Excrement sheep 3...	.10	.05	.25	2.65	3.93	.....	.....	.....	19.53	26.07	45.60
4249	Excrement sheep 1...	.13	.24	7.14	3.33	2.24	7.17	18.01	5.79	23.80	23.97	47.77
4250	Excrement sheep 3...	.29	.06	9.05	4.20	2.20	.....	.....	.....	24.93	23.07	48.00
4251	Excrement sheep 4...	.28	.14	7.48	2.76	.64	.....	.....	.....	21.18	25.15	46.33
4254	Excrement sheep 1...	.06	.01	.79	3.53	2.33	5.68	10.07	4.11	14.18	31.19	45.37
4255	Excrement sheep 3...	.08	.02	.67	4.24	2.91	.....	.....	.....	13.30	32.13	45.43
4256	Excrement sheep 4...	.07	.08	.91	3.61	1.45	.....	.....	.....	14.23	32.28	46.51
4261	Excrement sheep 1...	.20	.23	.03	1.80	1.34	0.93	3.19	5.94	9.13	20.18	29.31
4262	Excrement sheep 3...	.23	.07	.07	1.72	1.36	.....	.....	.....	8.24	19.33	27.57
4263	Excrement sheep 4...	.16	.10	.04	1.89	1.63	.....	.....	.....	8.08	20.12	28.20
4279	Excrement sheep 1...	.08	.01	.02	4.45	4.48	.....	.....	.....	19.04	26.92	45.96
4280	Excrement sheep 3...	.08	.00	.30	5.35	4.48	.....	.....	.....	20.00	27.04	47.07
4281	Excrement sheep 4...	.06	.01	.40	5.11	3.44	.....	.....	.....	18.68	27.18	45.86
4548	Excrement sheep 4...	.07	0	.16	2.28	2.89	6.50	9.01	6.48	15.49	25.43	40.92
4549	Excrement sheep 5...	.06	.02	.29	2.75	2.76	.....	.....	.....	6.50	24.94	31.44
4550	Excrement sheep 6...	.08	.02	.21	2.79	2.74	.....	.....	.....	18.53	22.47	41.00
4554	Excrement sheep 1...	.05	.01	.99	2.63	2.60	11.69	15.37	5.16	20.53	26.83	47.36

4555	Excrement sheep 3...	.07	.02	.68	4.62	3.16	.....	.....	.....	20.70	27.16	47.86
4556	Excrement sheep 5...	.06	.02	.58	4.42	2.77	.....	.....	.....	19.85	26.65	46.50
4559	Excrement sheep 1...	.09	.00	.32	7.38	7.65	7.52	15.31	8.82	24.13	25.72	49.85
4560	Excrement sheep 4...	.07	.01	.57	5.37	5.43	.....	.....	.....	22.14	27.41	49.55
4561	Excrement sheep 5...	.08	.01	.22	4.90	5.64	.....	.....	.....	23.52	26.99	50.51
4665	Excrement sheep 1...	.12	.15	.98	3.31	2.00	5.41	9.97	4.85	14.82	23.36	38.18
4666	Excrement sheep 4...	.22	0	.83	3.59	2.05	.....	.....	.....	15.40	23.78	39.18
4667	Excrement sheep 5...	.09	.13	1.32	3.00	1.86	.....	.....	.....	13.88	24.77	38.65

TABLE 9.—NUTRIENTS FED, DIGESTED AND EXCRETED, IN GRAMS PER PERIOD.

	Sugars		Starch.	Reducing sugar from hemicellulose.	Rendered insoluble by acid.	Residue.	Total N. F. E. soluble.	Insoluble N. F. E.	Sugar by 1 1-4 per cent sulphuric.	Sugar by 1 1-4 per cent caustic.	Insoluble precipitate from caustic.
	Mono.	Di.									
Digestion Period No. 1 with Cowpea Hay.											
Sheep No. 1—											
Fed 4000 gms. No. 3220-1	53.20	48.8	.....	.....	.....	.....	.....	.....	.....	.....	.....
Excreted 1729 gms. No. 3222	5.0	0.5	.....	.....	.....	.....	.....	.....	.....	.....	.....
Digested	48.2	48.3	.....	.....	.....	.....	.....	.....	.....	.....	.....
Percentage digested from cowpea hay	90.6	98.9	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sheep No. 2—											
Total fed 4000 gms. No. 3220-1	53.20	48.8	.....	.....	.....	.....	.....	.....	.....	.....	.....
Eaten	53.2	48.8	.....	.....	.....	.....	.....	.....	.....	.....	.....
Excreted 1687 gms. No. 3223	5.4	.3	.....	.....	.....	.....	.....	.....	.....	.....	.....
Digested	47.6	48.5	.....	.....	.....	.....	.....	.....	.....	.....	.....
Percentage digested from cowpea hay	89.5	99.3	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average percentage digested	90.1	99.1	.....	.....	.....	.....	.....	.....	.....	.....	.....
Digestion Period No. 2 with Sorghum Hay.											
Sheep No. 1—											
Fed 4800 gms. No. 3224-5	233.3	31.2	61.9	19.2	174.2	391.2	1091.5	1154.0	410.4	80.2	.....
Excreted 1860 gms. No. 3258	.9	3.5	13.0	49.1	165.5	104.2	356.2	443.2	159.0	41.9	.....
Digested	232.4	27.7	48.9	0	8.7	287.0	735.3	711.2	251.4	38.3	.....
Percentage digested from Sorghum hay	99.6	88.9	78.9	0	4.9	73.3	67.3	61.6	61.3	47.8	.....
Sheep No. 2.—											
Total fed 4000 gms. No. 3224-5	194.4	26.0	51.6	16.0	.....	.....	909.6	962.0	342.0	66.8	.....
Excreted 1560 gms. No. 3259	.3	.5	10.5	39.6	.....	.....	308.4	358.6	133.4	35.1	.....
Digested	194.1	25.5	41.1	0	.....	.....	601.2	603.4	208.6	31.7	.....
Percentage digested from sorghum hay	99.8	98.1	79.6	0	.....	.....	66.1	62.7	61.0	47.5	.....

Sheep No. 3—											
Fed 4000 gms. No. 3224-5	194.4	26.0	51.6	16.00	145.2	326.0	909.6	962.0	342.0	66.8	
Residue 5 gms. No. 3224-5	.2	0	.1	0	.2	.4	1.1	1.2	.4	.1	
Eaten	194.2	26.0	51.5	16.0	145.0	325.6	908.5	960.8	341.6	66	
E'xcreted 1440 gms. No. 3260	.6	.1	10.9	37.7			287.0	341.7	123.1	32.4	
Digested	193.6	25.9	40.6	0			621.5	619.1	218.5	34.3	
Percentage digested	99.7	99.6	78.8	0			68.4	64.4	64.0	51.3	
Digestion Period No. 3 with Alfalfa Hay.											
Sheep No. 2—											
Fed 4400 gms. No. 3277-8	81.0	41.8	64.2	156.2	209.0	531.1	837.7	1004.5	112.2	68.2	
Residue 3 gms. No. 3277-8	.1	0	.1	.1	.1	.4	.8	.2	.1	0	
Eaten	80.9	41.8	64.1	156.1	208.9	530.7	836.9	1004.3	112.1	68.2	
Excreted 1667 gms. No. 3279	.3	.2	4.8	60.2	29.3	133.9	249.6	229.0	52.5	18.7	
Digested	80.6	41.6	59.3	95.9	179.6	396.8	587.3	775.3	59.6	49.5	
Percentage difdigested	99.5	99.5	92.5	61.4	85.9	74.7	70.2	77.2	53.2	72.6	
Sheep No. 3—											
Total fed 4400 gms. No. 3277-8	81.0	41.8	64.2	156.2			837.7	1004.5	112.2	68.2	
Excreted 1511 gms. No. 3280	1.5	.6	4.7	53.6			215.5	215.3	47.6	16.9	
Digested	79.5	41.2	59.5	102.6			622.2	789.2	64.6	51.3	
Percentage digested	98.1	98.5	92.7	65.7			74.3	78.6	57.6	75.2	
Sheep No. 4—											
Fed 4400 gms. No. 3277-8	81.0	41.8	64.2	156.2			837.7	1004.5	112.0	68.0	
Residue 86 gms. No. 3283	1.6	.8	1.3	3.1			23.2	7.4	2.2	1.3	
Eaten	79.4	41.0	62.9	153.3			814.5	997.1	109.8	66.9	
Excreted 1732 gms. No. 3281	1.7	1.4	2.4	64.9			242.5	243.9	54.6	19.4	
Digested	77.7	39.6	60.5	88.4			572.0	753.2	55.2	47.5	
Percentage digested	97.8	96.6	96.2	57.6			70.2	75.5	50.3	71.0	
Average percentage digested	98.5	98.2	93.8	61.6	85.9	74.7	71.6	77.1	53.7	72.9	
Digestion Period No. 4 with Johnson Grass Hay.											
Sheep No. 1—											
Fed 3600 gms. No. 3587-8	56.5	2.5	38.1	146.2	136.4	246.2	685.8	821.9	268.2	27.0	
Residue 110 gms. No. 3592	1.7	.1	1.2	4.5	4.2	7.5	20.9	25.1	8.2	.8	
Eaten	54.8	2.4	36.9	141.7	132.2	238.7	664.5	796.8	260.0	26.2	
Excreted 1720 gms. No. 3589	.7	.2	24.4	35.8	117.5	148.8	342.1	392.0	134.2	14.6	
Digested	54.1	2.2	12.5	105.9	14.7	89.9	322.4	404.8	125.8	11.6	
Percentage digested	98.7	91.3	33.5	74.7	11.1	37.6	48.5	50.8	48.4	44.3	

TABLE 9.—NUTRIENTS FED, DIGESTED AND EXCRETED, IN GRAMS PER PERIOD.

	Sugars		Starch.	Reducing sugar from hemicellulose.	Rendered insoluble by acid.	Residue.	Total N. F. E. soluble.	Insoluble N. F. E.	Sugar by 1 1-4 per cent sulphuric.	Sugar by 1 1-4 per cent caustic.	Insoluble precipitate from caustic.
	Mono.	Di.									
Digestion Period No. 3 with Johnson Grass Hay.											
Sheep No. 3—											
Total fed 3600 gms. No. 3587-8	56.5	2.5	38.1	146.2	.....	.....	685.4	821.9	268.2	27.0	.....
Residue 471 gms. No. 3593	7.4	.3	5.0	19.1	.....	.....	89.7	107.5	35.1	3.5	.....
Eaten	49.1	2.2	33.1	127.1	.....	.....	595.7	714.4	233.1	23.5	.....
Excreted 1476 gms. No. 3590	.4	.3	21.4	49.7	.....	.....	302.6	331.7	115.1	12.5	.....
Digested	48.7	1.9	11.7	77.4	.....	.....	293.1	382.7	118.0	11.0	.....
Percentage digested	99.2	86.4	35.3	60.9	.....	.....	49.2	53.6	50.6	46.8	.....
Sheep No. 4—											
Fed 3600 gms. No. 3587-8	56.5	2.5	38.1	146.2	.....	.....	685.4	821.9	268.2	27.0	.....
Residue 158 gms. No. 3594	2.5	.1	1.7	6.4	.....	.....	30.1	36.1	11.8	1.3	.....
Eaten	54.0	2.4	36.4	139.8	.....	.....	655.3	785.8	256.4	25.7	.....
Excreted 1637 gms. No. 3591	1.1	.2	19.0	46.2	.....	.....	329.8	377.2	127.7	13.9	.....
Digested	52.9	2.2	17.4	83.6	.....	.....	325.5	408.6	128.7	11.8	.....
Percentage digested	97.9	91.6	47.8	66.9	.....	.....	49.6	51.9	50.2	45.9	.....
Average percentage digested	98.6	89.9	38.9	67.5	11.1	37.6	49.1	52.1	49.7	45.7	.....
Digestion Period No. 5 with Oat Hay.											
Sheep No. 1—											
Fed 4000 gms. No. 3595-6	89.6	12.0	200.4	55.6	149.2	187.2	801.6	974.0	460.0	49.2	186.8
Residue 173 gms. No. 3599	3.9	.5	8.7	2.4	6.8	8.1	34.7	42.1	19.9	2.1	8.1
Eaten	85.7	11.5	191.7	53.2	142.4	179.1	766.9	931.9	440.1	47.1	178.7
Excreted 1281 gms. No. 3597	.4	.3	2.3	41.2	133.6	197.1	378.6	261.0	112.7	15.8	95.4
Digested	85.3	11.2	189.4	12.0	8.8	0	388.3	670.9	327.4	31.3	83.3
Percentage digested	99.5	97.4	98.8	22.5	6.2	0	50.6	71.9	74.4	66.4	46.6

Sheep No. 4—											
Total fed 4000 gms. No. 3595-6	89.6	12.0	200.4	55.6	.....	.....	801.6	974.0	460.0	49.2	186.8
Residue 242 gms. No. 3600	5.4	.7	12.1	3.4	.....	.....	48.5	58.9	27.8	3.0	11.3
Eaten	84.2	11.3	188.3	52.2	.....	.....	753.1	915.1	432.2	46.2	175.5
Excreted 1433 gms. No. 3598	.6	.4	1.4	48.6	.....	.....	290.0	304.8	126.1	17.6	106.8
Digested	83.6	10.9	186.9	3.6	.....	.....	463.1	610.3	306.1	28.6	68.7
Percentage digested	99.3	96.4	99.3	6.9	.....	.....	61.5	66.6	70.8	61.9	39.1
Average percentage digested	99.4	96.9	99.1	14.7	6.2	0	56.1	69.3	72.6	64.2	42.9
Digestion Period No. 6 with Burr Clover Hay.											
Sheep No. 2—											
Fed 4000 gms. No. 3609-10	46.8	4.4	76.0	126.0	257.6	348.0	980.0	296.4	116.0	68.0	134.4
Residue 5 gms. No. 3609-10	.1	0	.1	.2	.3	.4	1.2	.4	.1	.1	.2
Eaten	46.7	4.4	75.9	125.8	257.3	347.6	978.8	296.0	115.9	67.9	134.2
Excreted 1096 gms. No. 3623	.9	1.3	18.9	43.4	76.4	27.1	153.1	150.8	44.2	4.7	85.0
Digested	45.8	3.1	57.0	81.4	180.9	320.5	825.7	145.2	71.7	63.2	49.
Percentage digested	98.2	70.5	75.1	65.5	70.3	9 .2	84.4	48.9	61.9	93.1	36.7
Sheep No. 3—											
Total fed 4000 gms. No. 3609-10	46.8	4.4	76.0	126.0	.....	.....	980.0	296.4	116.0	68.0	134.4
Residue 15 gms. No. 3609-10	.2	0	.3	.5	.....	.....	3.7	1.1	.4	.3	.5
Eaten	46.6	4.4	75.7	125.5	.....	.....	976.3	295.3	115.6	67.7	133.9
Excreted 1110 gms. No. 3624	.4	.2	7.8	47.0	.....	.....	138.9	169.4	44.7	4.8	86.1
Digested	46.2	4.2	67.9	78.5	.....	.....	837.4	125.9	70.9	62.9	47.8
Percentage digested	99.1	95.4	89.7	62.5	.....	.....	85.7	42.6	61.3	92.9	35.7
Average percentage digested	98.7	82.9	82.4	64.0	70.3	92.2	85.1	45.8	61.6	93.0	36.2
Digestion Period No. 7 with Rice Straw.											
Sheep No. 2—											
Fed 3600 gms. No. 3625-6	55.8	54.0	212.4	111.2	79.6	111.2	552.6	798.2	404.2	34.2	171.4
Residue 53 gms. No. 3880	.8	.1	3.1	1.6	1.2	1.6	8.1	11.8	6.0	.5	2.5
Eaten	55.0	53.9	209.3	109.6	78.8	209.6	544.5	786.4	398.2	33.7	169.9
Excreted 1914 gms. No. 3877	1.2	.2	6.7	59.1	112.5	97.6	281.0	417.6	201.9	6.3	124.0
Digested	53.8	53.7	202.6	50.5	0	112.0	263.5	368.8	196.3	27.4	44.9
Percentage digested	97.8	99.8	96.8	46.1	0	53.4	48.4	46.7	49.3	81.3	26.6
Sheep No. 3											
Total fed 3600 gms. No. 3625-6	55.8	54.0	212.4	111.2	.....	.....	55.6	798.2	404.2	34.2	171.4
Residue 305 gms. No. 3881	4.7	.5	18.0	9.4	.....	.....	46.8	67.6	34.3	2.9	14.5
Eaten	51.1	53.5	194.4	101.8	.....	.....	505.8	730.6	369.9	31.3	156.9
Excreted 1933 gms. No. 3878	1.2	.2	10.8	60.9	.....	.....	274.1	44.6	203.9	6.4	125.3
Digested	49.9	53.3	183.6	40.9	.....	.....	231.7	283.7	166.0	24.9	31.6
Percentage digested	97.6	99.6	94.4	40.2	.....	.....	45.8	38.8	44.9	79.6	20.1

TABLE 9.—NUTRIENTS FED, DIGESTED AND EXCRETED, IN GRAMS PER PERIOD.

	Sugars		Starch.	Reducing sugar from hemicellulose.	Rendered insoluble by acid.	Residue.	Total N. F. E. soluble.	Insoluble N. F. E.	Sugar by 1 1-4 per cent sulphuric.	Sugar by 1 1-4 per cent caustic.	Insoluble precipitate from caustic.
	Mono.	Di.									
Digestion Period No. 7 with Rice Straw. Sheep No. 4—											
Fed 3600 gms. No. 3625-6	55.8	54.0	212.4	111.2	.....	.....	552.6	798.2	404.2	34.2	171.4
Residue 170 gms. No. 3882	2.6	.3	10.0	5.2	.....	.....	26.1	37.7	19.1	1.6	8.1
Eaten	53.2	53.7	202.4	106.0	.....	.....	526.5	760.5	585.1	32.6	163.6
Excreted 1912 gms. No. 3879	1.5	.7	6.7	48.8	.....	.....	282.0	434.2	201.7	6.3	123.9
Digested	51.7	53.5	195.7	57.2	.....	.....	244.5	326.3	183.4	26.3	39.4
Percentage digested	97.2	99.6	96.6	53.9	.....	.....	46.4	42.9	47.6	80.7	24.1
Average percentage digested	97.5	99.7	95.9	46.7	.....	53.4	46.9	42.6	47.3	80.5	23.6
Digestion Period No. 8 with Vetch Hay. Sheep No. 1—											
Fed 4000 gms. No. 3649-50	28.0	12.8	35.2	179.2	237.6	560.8	1083.4	408.4	135.6	4.4	100.8
Eaten	28.0	12.8	35.2	179.2	237.6	560.8	1083.6	408.4	.....	.....	.....
Excreted 1491 gms. No. 3700	1.2	.1	3.1	64.1	47.8	257.8	370.7	152.2	84.2	4.1	60.4
Digested	26.8	12.7	32.1	115.1	89.8	303.0	712.9	256.2	51.4	.3	40.4
Percentage digested	95.7	99.2	91.2	64.2	79.8	54.0	65.8	62.7	37.9	6.8	40.1
Average percentage digested	95.7	99.2	91.2	64.2	79.8	54.0	65.8	62.7	37.9	6.8	40.1
Digestion Period No. 9 with Buffalo Grass Hay. Sheep No. 3—											
Fed 4000 gms. No. 3883-4	106.4	33.6	162.8	15.6	.....	.....	766.4	1028.4	480.0	.....	257.6
Residue 5 gms. No. 3883-4	.1	0	.2	.0	.....	.....	1.0	1.3	.6	.....	.3
Eaten	106.3	33.6	162.6	15.6	.....	.....	765.4	1027.1	479.4	.....	257.3
Excreted 1881 gms. No. 3886	1.1	1.1	16.2	68.1	.....	.....	299.3	480.6	171.2	2.4	30.5
Digested	105.2	32.5	146.4	0	.....	.....	466.1	546.5	308.2	.....	226.8
Percentage digested	98.9	96.7	90.0	0	.....	.....	60.7	53.2	64.3	.....	88.2

Sheep No. 2—											
Total fed 4000 gms. No. 3883-4	106.4	33.6	162.8	15.6	90.8	175.6	776.4	1028.4	480.0	.....	257.6
Excreted 1701 gms. No. 3885	1.4	.2	13.1	56.8	63.8	126.1	270.8	440.0	154.8	2.2	27.6
Digested	105.0	33.4	149.7	0	27.0	49.5	505.6	588.4	325.2	.....	230.0
Percentage digested	98.7	99.4	91.9	0	91.9	28.2	65.1	57.2	67.7	.....	89.3
Average percentage digested	98.8	98.1	91.0	0	91.9	28.2	62.9	55.2	66.0	.....	88.6
Digestion Period No. 10 with Johnson Grass Hay.											
Sheep No. 1—											
Fed 4000 gms. No. 4238-9	108.8	23.6	75.6	34.4	141.6	306.8	849.2	940.0	426.0	18.0	262.8
Residue 10 gms. No. 4238-9	.2	.1	.2	.1	.4	.8	2.1	2.4	1.1	0	.7
Eaten	108.6	23.5	75.4	34.3	141.2	306.0	847.1	937.6	424.9	18.0	262.1
Excreted 1512 gms. No. 4240	1.4	.2	2.7	59.6	114.6	117.8	285.5	348.7	136.1	8.5	158.0
Digested	107.2	23.2	72.7	0	26.6	188.2	561.6	588.9	288.8	9.5	104.1
Percentage digested	98.7	99.1	96.8	0	18.8	61.5	66.3	62.8	68.0	52.8	39.7
Sheep No. 3—											
Total fed 4000 gms. No. 4238-9	108.8	23.6	75.6	34.4	.....	.....	849.2	940.0	426.0	18.0	262.8
Residue 5 gms. No. 4238-9	.1	.0	.1	.0	.....	.....	1.1	1.2	.5	.0	.3
Eaten	108.7	23.6	75.5	34.4	.....	.....	848.1	938.8	425.5	18.0	262.5
Excreted 1577 gms. No. 4241	1.7	.2	4.1	61.3	.....	.....	295.1	416.2	141.9	8.8	164.8
Digested	107.0	23.4	71.4	0	.....	.....	553.0	522.6	283.6	9.2	97.7
Percentage digested	98.4	99.1	94.6	0	.....	.....	65.2	55.6	66.6	51.1	27.2
Sheep No. 4—											
Fed 4000 gms. No. 4238-9	108.8	23.6	75.6	34.4	.....	.....	849.2	940.0	426.0	18.0	262.8
Residue 5 gms. No. 4238-9	.1	0	.1	.0	.....	.....	1.1	1.2	.5	0	.3
Eaten	108.7	23.6	75.5	34.4	.....	.....	848.1	938.8	425.5	18.0	262.5
Excreted 1634 gms. No. 4242	1.6	.8	4.1	64.1	.....	.....	319.1	426.0	147.1	9.2	170.8
Digested	107.1	22.8	71.4	0	.....	.....	529.0	512.8	278.4	8.8	91.7
Percentage digested	98.5	96.6	94.5	0	.....	.....	62.3	54.6	65.4	48.9	34.9
Average percentage digested	98.5	98.3	95.2	0	18.8	61.5	64.6	57.7	66.7	50.9	33.9
Digestion Period No. 11 with Baled Millet.											
Sheep No. 1—											
Fed 4000 gms. No. 4247-8	94.0	39.2	459.6	344.4	131.2	98.8	1184.8	730.8	358.8	19.2	173.2
Residue 34 gms. No. 4247-8	.8	.3	3.9	2.9	1.1	.8	10.0	6.2	3.0	.2	1.5
Eaten	93.2	38.9	455.5	341.5	130.1	98.0	1174.8	724.6	355.8	19.0	171.7
Excreted 1686 gms. No. 4249	2.2	4.1	120.4	37.8	120.9	97.6	401.3	404.2	173.7	7.2	140.8
Digested	91.0	34.8	335.1	303.7	9.2	.4	773.5	320.4	182.1	11.8	30.9
Percentage digested	97.6	89.4	73.6	88.9	7.1	0.4	65.8	44.2	51.2	62.1	18.0

TABLE 9.—NUTRIENTS FED, DIGESTED AND EXCRETED, IN GRAMS PER PERIOD.

	Sugars		Starch.	Reducing sugar from hemicellulose.	Rendered insoluble by acid.	Residue.	Total N. F. E. soluble.	Insoluble N. F. E.	Sugar by 1,1-4 per cent sulphuric.	Sugar by 1 1-4 per cent caustic.	Insoluble precipitate from caustic.
	Mono.	Di.									
Digestion Period No. 11 with Baled Millet.											
Sheep No. 3—											
Total fed 4000 gms. No. 4247-8	94.0	39.2	459.6	344.4	.....	.....	1184.8	730.8	358.8	19.2	173.2
Residue 20 gms. No. 4247-8	.5	.2	2.3	1.7	.....	.....	5.9	3.8	1.8	.1	.9
Eaten	93.5	39.0	457.3	342.7	.....	.....	1178.9	727.0	357.0	19.1	172.3
Excreted 1564 gms. No. 4250	4.5	.9	142.5	34.3	.....	.....	390.0	360.8	161.1	6.7	130.6
Digested	89.0	38.1	314.8	308.4	.....	.....	788.9	366.2	195.9	12.4	41.7
Percentage digested	95.2	97.7	68.8	89.9	.....	.....	66.9	50.3	54.9	64.9	24.2
Sheep No. 4—											
Fed 4000 gms. No. 4247-8	94.0	39.2	459.6	344.4	.....	.....	1184.8	730.8	358.8	19.2	173.2
Residue 30 gms. No. 4247-8	.7	.3	3.4	2.6	.....	.....	8.9	5.5	2.7	.1	1.3
Eaten	93.3	38.9	456.2	341.8	.....	.....	1176.9	725.3	356.1	19.1	171.9
Excreted 1704 gms. No. 4251	4.8	2.4	127.2	10.9	.....	.....	360.9	428.6	175.5	7.3	142.3
Digested	88.5	36.5	329.0	330.9	.....	.....	816.0	296.7	180.6	11.8	29.6
Percentage digested	94.8	93.8	72.1	96.8	.....	.....	69.3	40.9	50.7	61.5	17.2
Average percentage digested	95.9	93.6	71.5	91.9	7.1	0.4	67.3	45.1	52.3	62.8	19.8
Digestion Period No. 12 with Bermuda Hay.											
Sheep No. 1—											
Fed 4000 gms. No. 4252-3	88.0	56.4	43.2	28.4	105.2	235.6	702.0	1148.4	620.0	41.2	240.8
Residue 12 gms. No. 4252-4	.3	.2	.1	.1	.3	.7	2.1	3.4	1.9	.1	.7
Eaten	87.7	56.2	43.1	28.3	104.9	234.9	699.9	1145.0	618.1	41.1	240.1
Excreted 1920 gms. No. 4254	1.2	.2	15.2	44.7	109.1	78.9	272.3	598.8	251.9	23.0	169.0
Digested	86.5	56.0	27.9	.....	.....	156.0	427.6	546.2	366.2	18.1	71.1
Percentage digested	98.6	99.6	64.7	0	0	66.4	61.1	47.7	59.2	44.0	29.6

Sheep No. 3—											
Total fed 4000 gms. No. 4252-3	88.0	56.4	43.2	28.4	.....	.....	702.0	1148.4	620.0	41.2	240.8
Residue 12 gms. No. 4252-4	.3	.2	.1	.1	.....	.....	2.1	3.1	1.9	.1	.7
Eaten	87.7	56.2	43.1	28.3	.....	.....	699.9	1145.3	618.1	41.1	240.1
Excreted 2110 gms. No. 4255	1.7	.4	14.1	61.4	.....	.....	280.6	677.9	276.8	25.3	185.7
Digested	86.0	55.8	29.0	0	.....	.....	419.3	467.4	341.3	15.8	54.4
Percentage digested	98.1	99.3	67.3	0	.....	.....	59.9	40.8	55.2	38.4	22.7
Sheep No. 3—											
Fed 4000 gms. No. 4252-3	88.0	56.4	43.2	28.4	.....	.....	702.0	1148.4	620.0	41.2	240.8
Residue 15 gms. No.	.3	.2	.2	.1	.....	.....	2.6	4.3	2.3	.2	.9
Eaten	87.7	56.2	43.0	28.3	.....	.....	699.4	1144.1	617.7	41.0	239.9
Excreted 2044 gms. No. 4256	1.4	1.6	18.6	29.6	.....	.....	290.9	659.8	268.2	24.5	179.9
Digested	86.3	54.6	24.4	0	.....	.....	408.5	484.3	349.5	16.5	60.0
Percentage digested	98.4	97.1	56.7	.....	.....	.....	58.4	42.3	56.6	40.2	25.0
Average percentage digested	98.4	98.7	62.9	0	.....	.....	59.8	43.6	57.0	40.9	25.8
Digestion Period No. 13 with Peanut Hay.											
Sheep No. 1—											
Fed 4000 gms. No. 4259-60	90.8	87.2	138.0	14.4	158.8	653.2	1329.6	266.0	72.0	30.0	.....
Excreted 1335 gms. No. 4261	2.7	3.1	.4	17.8	12.4	78.5	121.9	269.4	58.7	8.0	.....
Digested	88.1	84.1	137.6	0	146.4	574.7	1207.5	0	13.3	22.0	.....
Percentage digested	97.0	96.4	99.7	.....	92.2	87.9	90.8	.....	18.5	73.3	.....
Sheep No. 3—											
Total fed 4000 gms. No. 4259-60	90.8	87.2	138.0	14.4	.....	.....	1329.6	266.0	72.0	30.0	.....
Excreted 1246 gms. No. 4262	2.9	.9	.9	17.0	.....	.....	103.0	240.9	54.8	7.5	.....
Digested	87.9	86.3	137.1	0	.....	.....	1226.6	25.1	17.2	22.5	.....
Percentage digested	96.8	98.9	99.3	0	.....	.....	92.2	9.4	23.9	75.0	.....
Sheep No. 4—											
Fed 4000 gms. No. 4259-60	90.8	87.2	138.0	14.4	.....	.....	1329.6	266.0	72.0	30.0	.....
Excreted 1315 gms. No. 4263	2.1	1.3	.5	21.4	.....	.....	106.3	264.6	57.9	7.9	.....
Digested	88.7	85.9	137.5	0	.....	.....	1223.3	1.4	14.1	22.1	.....
Percentage digested	97.7	98.5	99.6	0	.....	.....	92.0	.5	19.6	73.7	.....
Average percentage digested	97.2	97.9	99.5	0	92.2	87.9	91.7	3.3	20.7	74.0	.....

TABLE 9—NUTRIENTS FED, DIGESTED AND EXCRETED, IN GRAMS PER PERIOD.

	Sugars		Starch.	Reducing sugar from hemicellulose.	Rendered in soluble by acid.	Residue.	N. F. E. soluble.	Insoluble N. F. E.	Sugars by 1 1-4 per cent sulphuric.	Sugars by 1 1-4 per cent caustic.	Insoluble precipitate from caustic.
	Mono.	Di.									
Digestion Period No. 14 with Para Grass.											
Sheep No. 1											
Fed 4000 gms. No. 4277-8	174.0	35.2	.....	108.0	.....	.....	922.8	924.0	.....	.....	.....
Residue 212 gms. No. 4282	9.2	1.9	.....	5.7	.....	.....	27.7	49.0	.....	.....	.....
Eaten	164.8	33.3	.....	103.3	.....	.....	895.1	875.0	.....	.....	.....
Excreted 2043 gms. No. 4279	1.6	.2	.4	91.4	.....	.....	389.0	550.0	.....	.....	.....
Digested	163.2	33.1	.....	11.9	.....	.....	506.1	325.0	.....	.....	.....
Percentage digested	99.0	99.4	.....	11.5	.....	.....	.....	37.1	.....	.....	.....
Sheep No. 3—											
Total fed 4000 gms. No. 4277-8	174.0	35.2	.....	108.0	.....	.....	922.8	924.0	.....	.....	.....
Residue 40 gms. No. 4283	1.7	.4	.....	1.1	.....	.....	5.2	9.2	.....	.....	.....
Eaten	172.3	34.8	.....	106.9	.....	.....	917.6	914.8	.....	.....	.....
Excreted 2175 gms. No. 4280	1.7	0.0	.....	97.4	.....	.....	435.7	587.9	.....	.....	.....
Digested	170.6	34.8	.....	9.5	.....	.....	481.9	326.9	.....	.....	.....
Percentage digested	99.0	100.0	.....	8.8	.....	.....	.....	35.7	.....	.....	.....
Sheep No. 4—											
Fed 4000 gms. No. 4277-8	174.0	35.2	.....	104.0	.....	.....	922.8	924.0	.....	.....	.....
Residue 648 gms. No. 4287	28.2	5.7	.....	17.5	.....	.....	84.7	149.7	.....	.....	.....
Eaten	145.8	29.5	.....	90.5	.....	.....	838.1	774.3	.....	.....	.....
Excreted 1751 gms. No. 4281	1.1	.2	.....	60.2	.....	.....	327.1	475.9	.....	.....	.....
Digested	144.7	29.3	.....	30.3	.....	.....	511.0	298.4	.....	.....	.....
Percentage digested	83.1	99.3	.....	33.4	.....	.....	61.0	39.8	.....	.....	.....
Average percentage digested	93.7	99.6	.....	17.9	.....	.....	20.8	37.5	.....	.....	.....

Digestion Period No. 15 with Kafir Fodder.											
Sheep No. 5—											
Fed 4000 gms. No. 4546-7	188.0	23.6	53.2	10.8	94.8	402.0	963.6	814.0	404.0	14.0	.....
Excreted 1409 gms. No. 4548	1.0	0	2.3	40.7	91.6	91.3	218.4	358.3	145.1	6.3	.....
Digested	187.0	23.6	50.9	0	3.2	310.7	745.2	455.7	258.9	7.7	.....
Percentage digested	99.4	100.0	95.7	0	3.3	77.3	77.3	55.9	64.1	55.2	.....
Sheep No. 5—											
Total fed 4000 gms. No. 4546-7	188.0	23.6	53.2	10.8	94.8	402.0	963.6	814.0	404.0	14.0	.....
Excreted 1433 gms. No. 4549	.9	.3	4.2	35.5	.....	.....	93.1	357.4	147.6	6.4	.....
Digested	187.1	23.3	49.0	0	.....	.....	870.5	456.6	256.4	7.6	.....
Percentage digested	99.5	98.7	92.1	0	.....	.....	90.5	56.1	63.5	54.5	.....
Sheep No. 6—											
Fed 4000 gms. No. 4546-7	188.0	23.6	53.2	10.8	.....	.....	963.6	814.0	404.0	14.0	.....
Residue 308 gms. No. 4551	.4	1.8	4.1	1.6	.....	.....	74.2	62.7	31.1	1.1	.....
Eaten	187.6	21.8	49.1	9.2	.....	.....	889.4	751.3	372.9	12.9	.....
Excreted 1567 gms. No. 4550	1.3	.3	3.3	43.0	.....	.....	290.4	352.1	161.4	7.1	.....
Digested	186.3	21.5	45.8	0	.....	.....	599.0	399.2	211.5	5.8	.....
Percentage digested	99.3	98.6	93.3	.....	.....	.....	67.3	53.1	56.7	45.0	.....
Average percentage digested	99.4	99.1	93.7	0	3.3	77.3	78.4	55.0	61.4	51.6	.....
Digestion Period No. 16 with Guam Grass.											
Sheep No. 1—											
Fed 4000 gms. No. 4552-3	100.8	22.8	45.6	17.2	232.4	318.4	909.6	1075.6	498.0	17.2	325.2
Excreted 1899 gms. No. 4554	1.0	.2	18.7	49.4	222.0	98.0	389.9	509.5	241.6	12.5	179.1
Digested	99.8	22.6	26.9	0	10.4	220.4	519.7	566.1	256.4	4.7	146.1
Percentage digested	99.0	99.1	58.9	0	4.5	69.2	57.1	52.6	51.5	27.3	44.9
Sheep No. 3—											
Total fed 4000 gms. No. 4552-3	100.8	22.8	45.6	17.2	.....	.....	909.6	1075.6	498.0	17.2	325.2
Excreted 1888 gms. No. 4555	1.3	.4	12.9	59.7	.....	.....	390.8	513.0	240.2	12.5	178.0
Digested	99.5	22.4	32.7	0	.....	.....	518.8	562.6	257.8	4.7	147.2
Percentage digested	98.7	98.2	71.7	0	.....	.....	57.0	52.3	51.8	27.3	45.3
Sheep No. 5—											
Fed 4000 gms. No. 4552-3	100.8	22.8	45.6	17.2	.....	.....	909.6	1075.6	498.0	17.2	325.2
Excreted 2015 gms. No. 4556	1.2	.4	11.6	55.8	.....	.....	400.0	537.0	256.3	13.3	190.0
Digested	99.6	22.4	34.0	0	.....	.....	509.6	538.6	241.7	3.9	135.2
Percentage digested	98.7	98.2	74.5	0	.....	.....	56.0	50.1	48.5	22.7	41.6
Average percentage digested	98.8	98.5	68.4	0	4.5	69.2	63.4	51.7	50.6	25.8	43.9

TABLE 7.—NUTRIENTS FED, DIGESTED AND EXBRETED, IN GRAMS PER PERIOD.

	Sugars		Starch.	Reducing sugar from hemicellulose.	Ren-soluble soluble by acid.	Residue.	N. F. E. soluble.	Insoluble N. F. E.	Sugars by 1 1-4 per cent sulphuric.	Sugars by 1 1-4 caustic.	Insoluble precipitate from caustic.
	Mono.	Di.									
Digestion Period No. 17 with Corn Shucks. Sheep No. 1—											
Fed 3200 gms. No. 4557-8	43.8	5.4	64.3	268.8	59.2	245.1	805.4	838.9	485.8	272.0	120.0
Fed 45 gms. No. 4557-8	.6	.1	.9	3.8	.8	3.4	11.3	13.2	6.8	.4	1.7
Total fed	44.4	5.5	65.2	272.6	60.0	248.5	816.7	852.1	492.6	272.4	121.7
Excreted 1350 gms. No. 4559	1.2	0	4.3	103.3	101.6	119.1	345.8	447.2	160.7	8.8	96.8
Digested	43.2	5.5	60.9	169.3	0	129.4	470.9	404.9	331.9	263.6	24.9
Percentage digested	97.5	100.0	93.4	62.1	0	52.1	57.6	47.5	67.4	96.8	20.5
Sheep No. 4—											
Total fed 3200 gms. No. 4557-8	43.8	5.4	64.3	268.8	.....	.....	805.4	838.9	485.8	272.0	120.0
Added 12 gms. No. 4557-8	.2	.0	.2	1.0	.....	.....	3.0	3.5	1.8	.1	.5
Eaten	44.0	5.4	64.5	269.8	.....	.....	808.4	842.4	487.6	272.1	120.5
Excreted 1268 gms. No. 4560	.9	.1	7.2	69.0	.....	.....	280.7	347.6	150.9	8.2	90.9
Digested	43.1	5.3	57.3	200.8	.....	.....	527.7	494.8	336.7	263.9	29.6
Percentage digested	97.9	98.1	88.8	74.4	.....	.....	65.2	58.7	69.0	97.0	24.6
Sheep No. 5—											
Fed 3200 gms. No. 4557-8	43.8	5.4	64.3	268.8	.....	.....	805.4	838.9	485.8	272.0	120.0
Excreted 1147 gms. No. 4561	.9	.1	2.6	64.9	.....	.....	269.9	308.5	136.5	7.5	82.2
Digested	42.9	5.3	61.7	203.9	.....	.....	535.5	530.4	349.3	264.5	37.8
Percentage digested	97.9	98.1	95.9	75.8	.....	.....	66.4	63.2	71.9	97.2	31.5
Average percentage digested	97.8	98.7	92.7	70.8	.....	52.1	63.1	56.5	69.4	97.0	28.9
Digestion Period No. 18 with Honduras Rice Straw (baled) Sheep No. 1—											
Fed 3200 gms. No. 4663-4	21.8	3.8	55.0	121.3	82.6	252.8	537.0	759.0	320.0	272.2	.....
Residue 3 gms. No. 4663-4	.0	.0	.1	.1	.1	.2	.5	.7	.3	.0	.....
Eaten	21.8	3.8	54.9	121.2	82.5	252.6	536.5	758.3	319.7	27.2	.....
Excreted 1691 gms. No. 4665	2.0	2.5	16.6	33.8	91.6	82.0	250.6	395.0	153.0	15.2	.....
Digested	19.8	1.3	38.3	87.4	0	170.6	285.9	363.3	166.7	12.0	.....
Percentage digested	90.8	34.2	69.8	72.1	0	67.5	53.3	47.9	52.1	44.1	.....

Sheep No. 4—											
Total fed 3200 gms. No. 4663-4	21.8	3.8	55.0	121.3			537.0	759.0	320.0	27.2	
Added 45 gms. No. 4668	.3	.1	.8	1.7			7.5	11.7	4.5	.4	
Eaten	22.1	3.9	55.8	123.0			544.5	747.3	324.5	27.6	
Excreted 1708 gms. No. 4666	3.8	0.0	15.2	35	.0		263.0	406.2	154.6	15.4	
Digested	18.3	3.9	40.6	88.0			281.5	341.1	169.9	12.2	
Percentage digested	82.8	100.0	72.7	71.5			51.7	45.6	52.3	44.2	
Sheep No. 5—											
Fed 3200 gms. No. 4663-4	21.8	3.8	55.0	121.3			537.0	759.0	320.0	27.2	
Residue 777 gms. No. 4669	5.3	.9	13.4	29.4			130.4	184.3	77.7	6.6	
Eaten	16.5	2.9	41.6	91.9			406.6	575.7	242.3	20.6	
Excreted 1450 gms. No. 4667	1.3	1.9	19.1	27.0			201.3	259.2	131.2	13.1	
Digested	15.2	1.0	22.5	64.9			205.3	216.5	111.1	7.5	
Percentage digested	92.1	34.5	54.1	70.6			50.5	37.2	45.9	36.4	
Average percentage digested	88.6	56.2	65.5	71.4		67.5	51.8	43.6	50.1	41.6	

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SUMMARY AND CONCLUSIONS.

1. The roughages contain only small percentages of sugars and starches, which are highly digestible.

2. Pentosans are destroyed by N/50 acid and alkali in the analytical process employed. A black powder is also formed.

3. The nitrogen-free extract of legumes is on an average more readily soluble in N/50 acid and alkali than that of non-legumes.

4. The mother substances of the reducing sugars formed from the material dissolved by N/50 acid and alkali vary decidedly in digestibility in the various tests.

5. The nitrogen-free extract soluble in N/50 acid and alkali is, as a rule, digested to a greater extent than that not soluble.

6. The black insoluble substance formed during the conversion of the material dissolved by N/50 acid and alkali into sugars is largely composed of non-nitrogenous material other than pentosans.

7. Much larger quantities of material yielding sugars are dissolved by $1\frac{1}{4}$ per cent. caustic soda.

8. Boiling with caustic soda dissolves only small quantities of material converted into sugars, but large quantities converted into an insoluble black precipitate during the process.

9. It is probable that the substances dissolved by acid and alkali contain considerable proportions of compounds other than carbohydrates.